DEVELOPMENTAL TESTBED CENTER (DTC)

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Acknowledgements:
Bill Kuo, Louisa Nance, Barbara Brown, Kevin Kelleher

Developmental Testbed Center

5th NOAA Testbed Workshop, April 16-18, 2014

OUTLINE / SUMMARY

- **Where DTC has been**
  - Operations to Research (O2R) in Numerical Weather Prediction
    - Code repositories, helpdesks, tutorials, etc

- **AOP-13 Highlights**
  - Mesoscale modeling, Hurricane modeling, Data Assimilation, Ensemble forecasting, Verification
    - Testing & Evaluation of baseline & other methodologies, Visitor Program

- **Future Directions**
  - Discussions on scope of DTC
    - Improve current & next generation NWP systems
    - New Cooperative Agreement
  - Build modern NWP IT Environment (NITE)
  - Strengthen collaboration with other NOAA testbeds & programs

OVERVIEW

- **Interagency collaboration**
  - To accelerate NWP Research to Operations (R2O) transition
  - NOAA (OAR, NWS-HFIP), AFWA, NCAR (RAL)

- **O2R** – Major accomplishments
  - Code repositories
    - WRF, GSI, HWRF, MET for community use; SREF for internal T&E
  - Helpdesks, workshops, tutorials, etc
  - Testing environment functionally similar to EMC's

- **R2O** – Significant T&E work
  - Reference configurations
  - Improvements to operational systems
  - Other experiments informing decisions regarding operational systems
  - Visitor Program

Mesoscale Modeling Task

Jamie Wolff et al.

Version T&E Results

WRFv3.4

WRFv3.4.1

WRFv3.5

Version Testing and Evaluation (T&E)

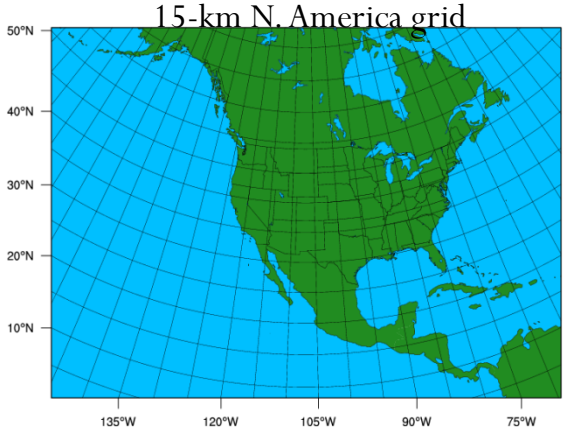
- Developmental Testbed Center (DTC) testing philosophy:
  - Conduct comprehensive testing and evaluation, including extensive objective verification
  - Provide a neutral and unbiased assessment
- WRF version testing:
  - Continually evolving code base
  - Prior to a release, WRF code run through large number of regression tests; however, extensive testing to evaluate forecast skill is not widely addressed
  - Modifications to address a specific issue may impact other aspects
- Is WRF improving? neutral? degrading? → Hard question to answer!
  - Highly configurable, many options - depends on the user's needs

Version Testing and Evaluation (T&E)

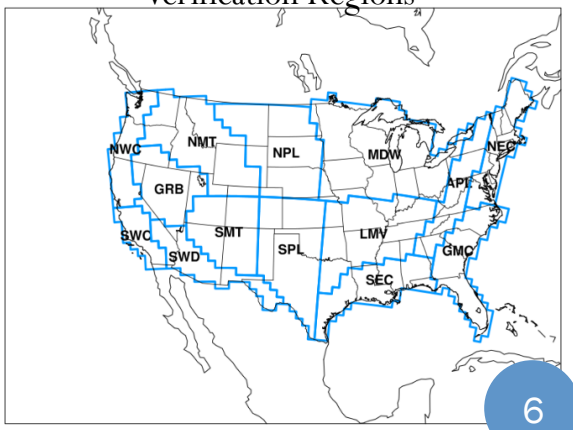
- End-to-end system: WPS, WRF, UPP, and MET
- Simulations: 48-h cold start forecasts every 36 h (3mo warm and cold season)
- AFWA Operational Configuration Physics Suite:

Microphysics	WSM6
Radiation	Dudhia/RRTM
Surface Layer	M-O similarity
LSM	Noah
PBL	YSU
Convection	Kain-Fritsch

15-km N. America grid



Verification Regions



- Evaluation:
  - Surface and Upper-air BCRMSE, Bias
    - Temperature, Dew Point Temperature, Winds
  - Pair-wise differences (v3.4-v3.4.1, v3.4.1-v3.5, v3.4-v3.5)
  - Statistical/Practical Significance

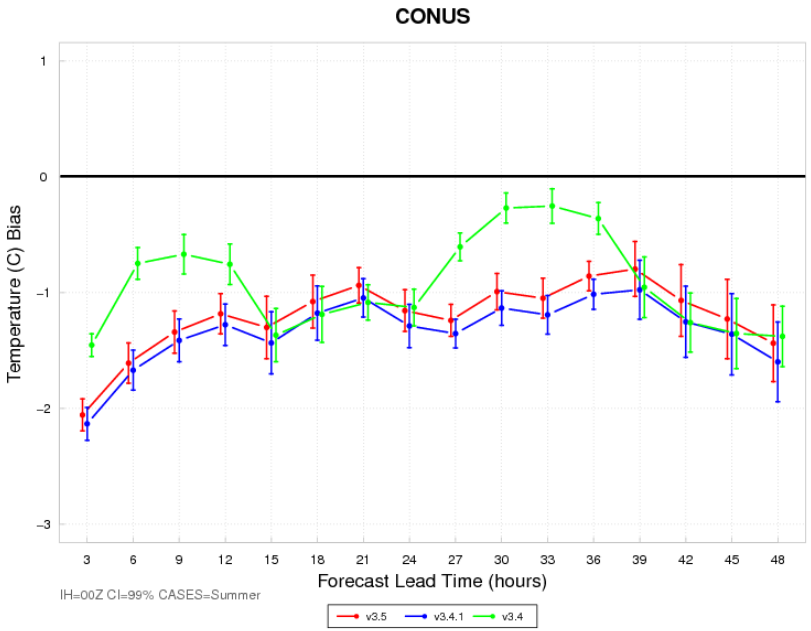
CONUS Sfc Temp Bias - Time Series

00 UTC Initializations

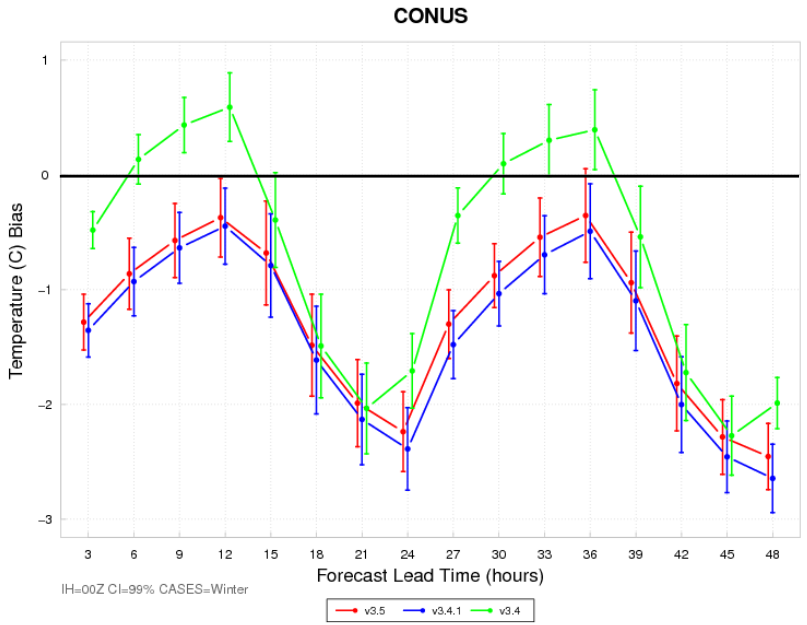
Larger warm bias

Larger cold bias

Summer



Winter



WRFv3.4 WRFv3.4.1 WRFv3.5

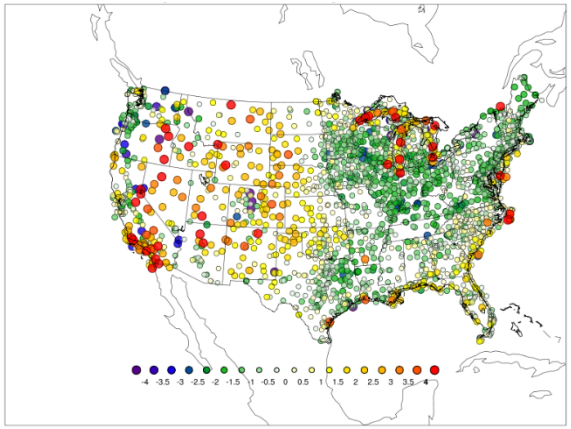
Lead Time	f03	f06	f09	f12	f15	f18	f21	f24	f27	f30	f33	f36	f39	f42	f45	f48
Summer	v3.4 *	v3.4 *	v3.4 *	v3.4 *	v3.5	v3.5 *	v3.5 *	v3.4 *	v3.4 *	v3.4 *	v3.4 *	v3.4 *	v3.5 *	v3.5 *	v3.5 *	--
Winter	v3.4 *	v3.4 *	v3.4 *	v3.5 *	v3.4 *	--	--	v3.4 *	v3.4 *	v3.4 *	v3.4 *	v3.5 *	v3.4 *	--	--	v3.4 *

Sfc Temp Bias – By Observation Station

00 UTC Initializations; Lead Time=36h (Valid 12 UTC)

v3.4 | v3.5

Summer



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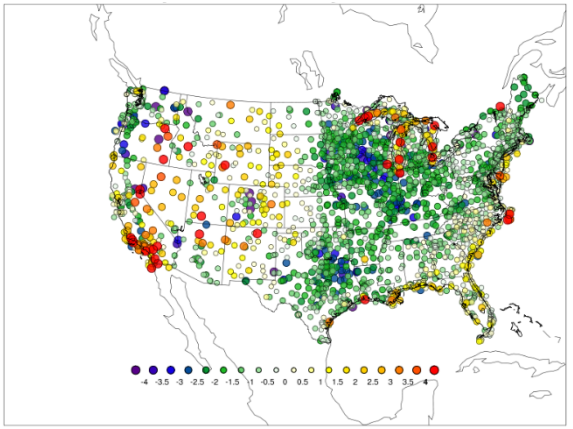

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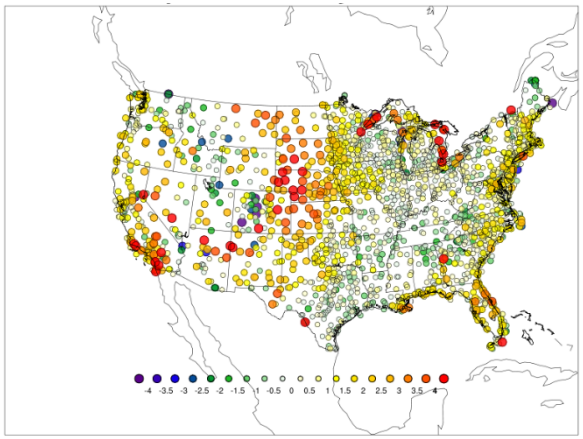
Winter



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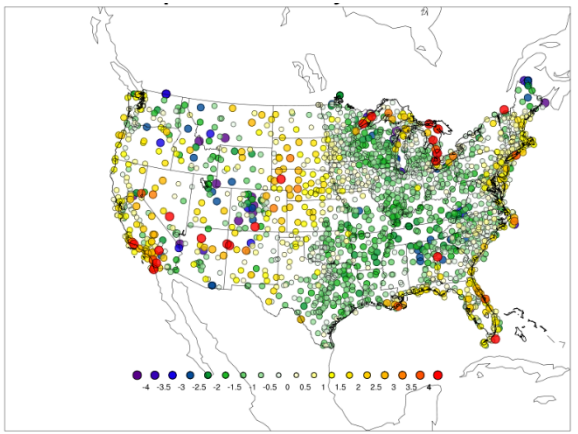


Config=AFWAOC_WRFv3.5 Season=WINTER Init=00UTC Fcst Hr=36h

DTC Hurricane Task

Ligia Bernardet

C. Holt, T. Brown, M. Biswas, D. Stark, L. Carson, T. Galarneau, X. Fang

External collaborators:

NOAA's Environmental Modeling Center

NOAA's Atlantic Oceanographic and Meteorological Laboratory

NOAA's Geophysical Fluid Dynamics Laboratory

NOAA's Earth System Research Laboratory

NCAR's Mesoscale and Microscale Meteorology Division

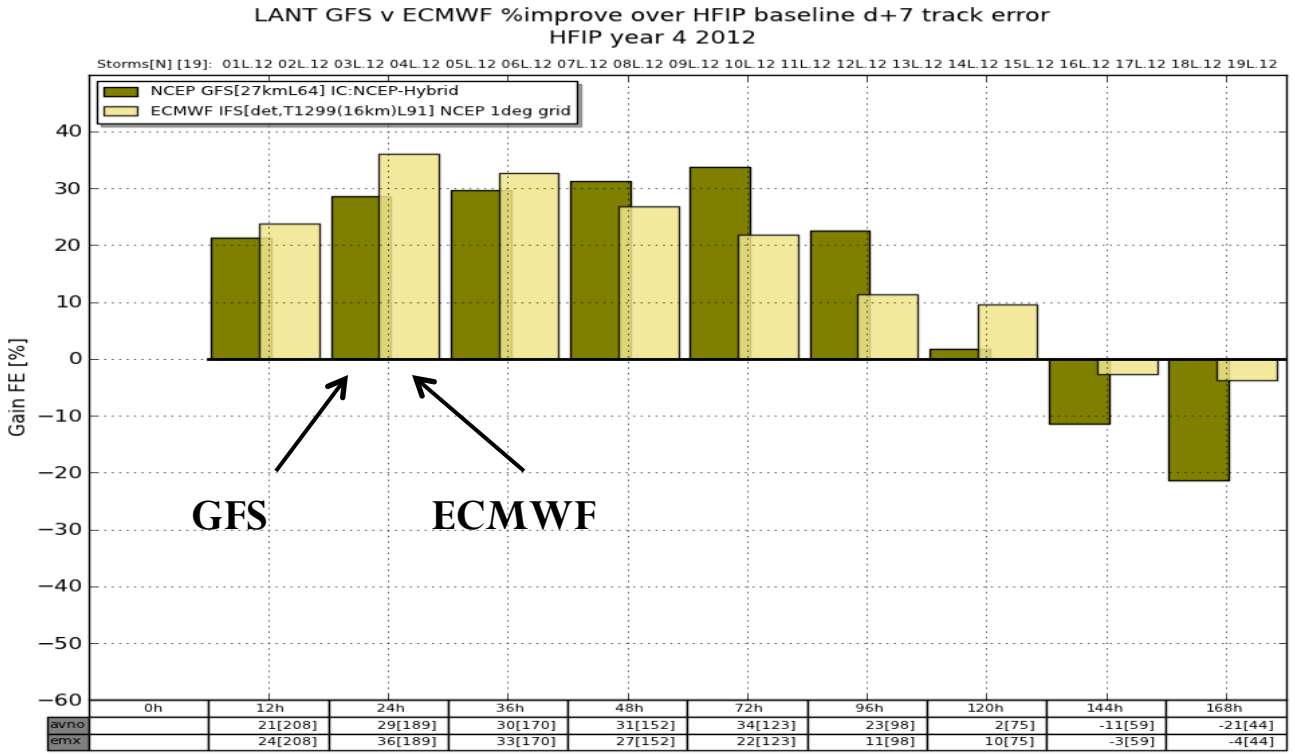
University of Rhode Island

Highlight

Diagnostic of GFS 5-day track errors

Courtesy: Mike Fiorino (NOAA/ESRL)

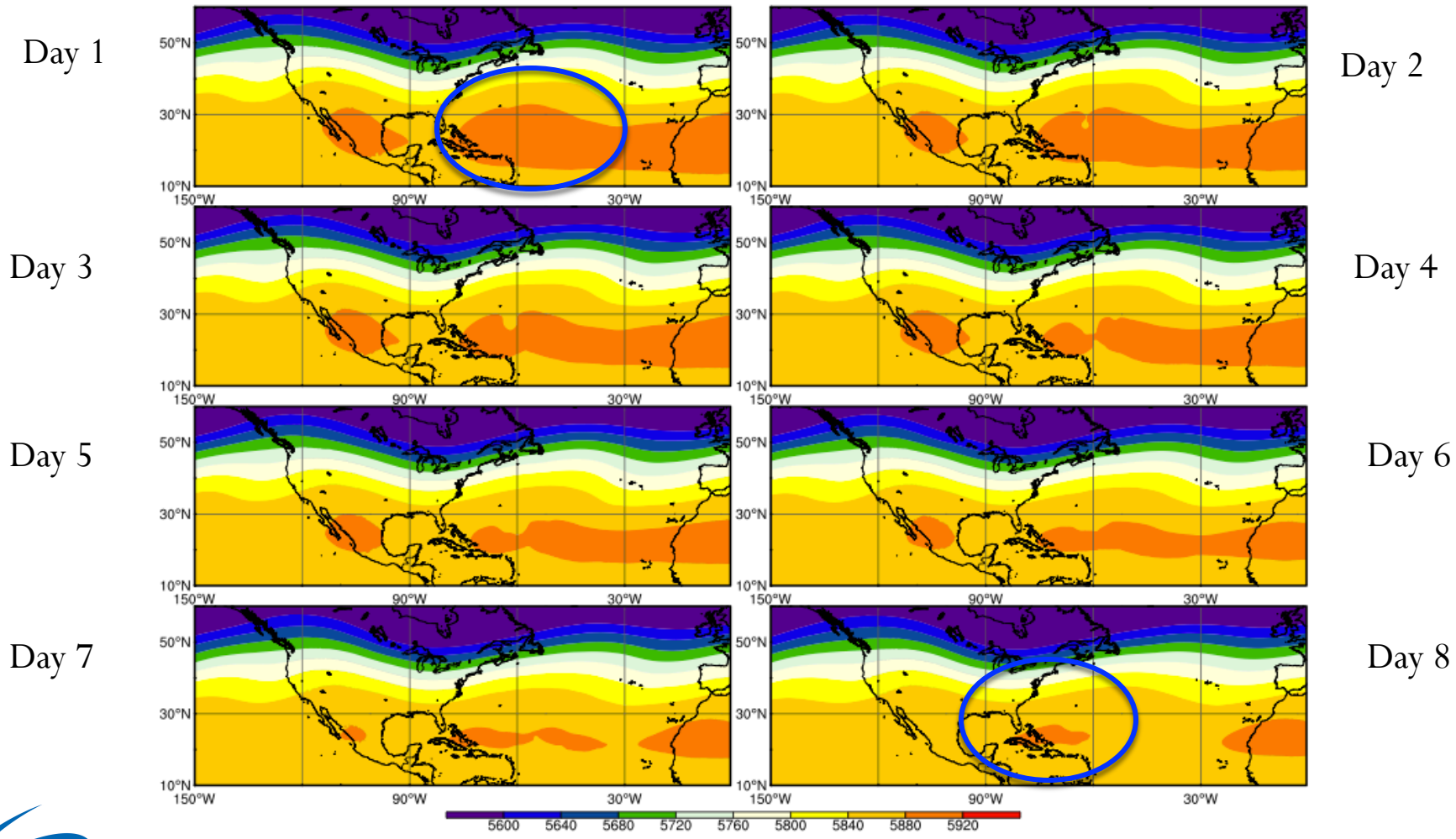
NCEP vs ECMWF track verification



- GFS better than ECMWF up to 2 days.
- GFS errors larger than ECMWF in days 6-7

Note: Only a few storms live enough to warrant 7 day forecasts

GFS 500-hPa height: 90-day mean

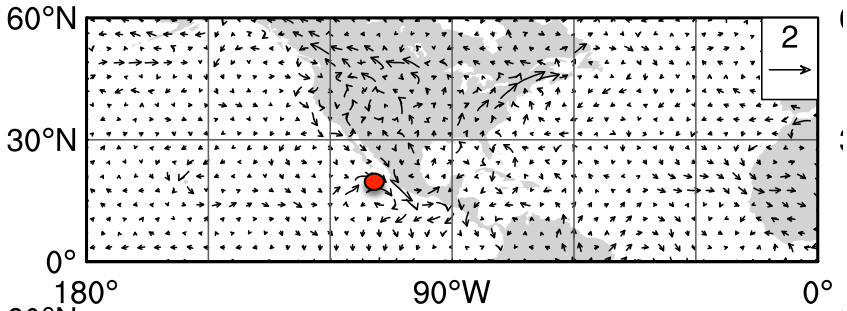


Pattern deamplifies with increasing forecast lead time – Physics problem?

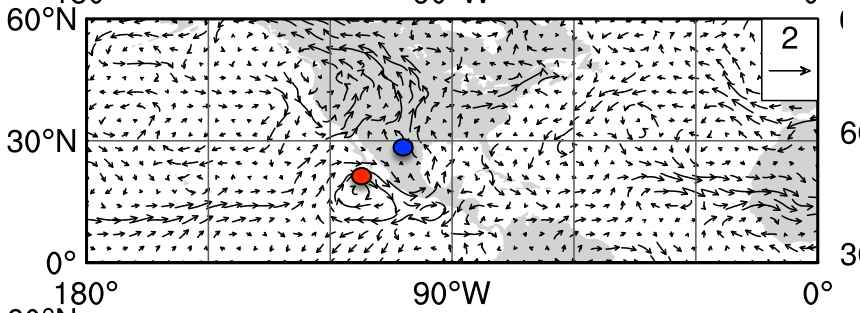
GFS wind 92-day mean: 1 Aug-31 Oct 2012

850-500 hPa mean wind errors

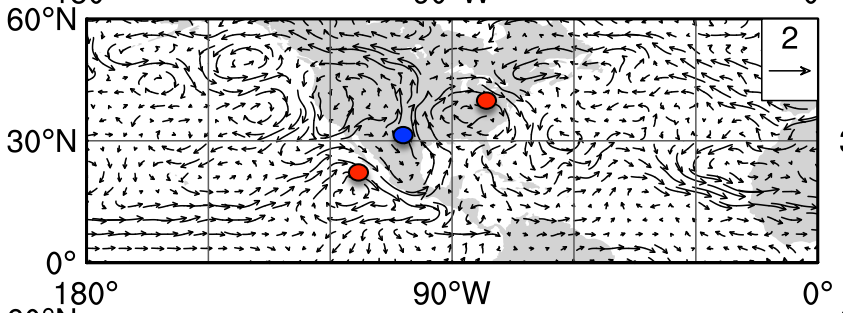
Day 1



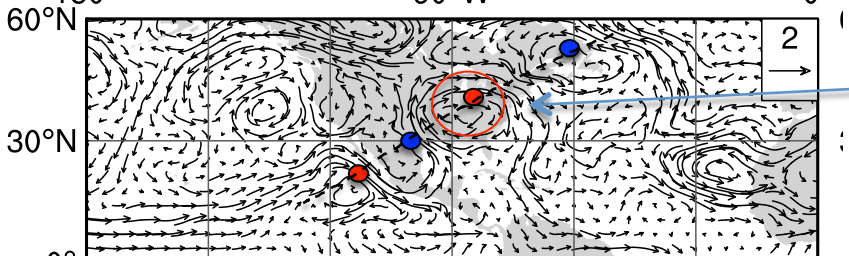
Day 3



Day 5



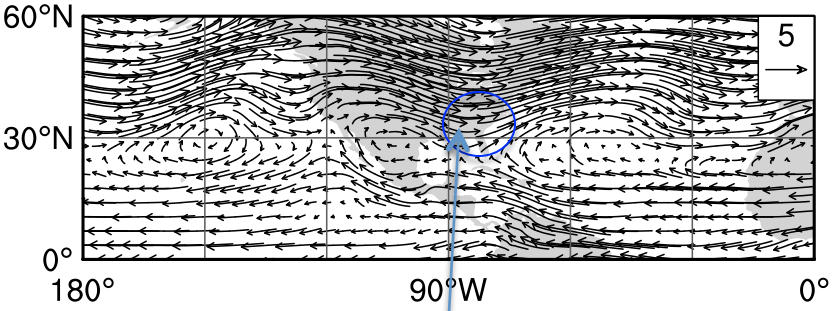
Day 7



= anticyclonic error

= cyclonic error

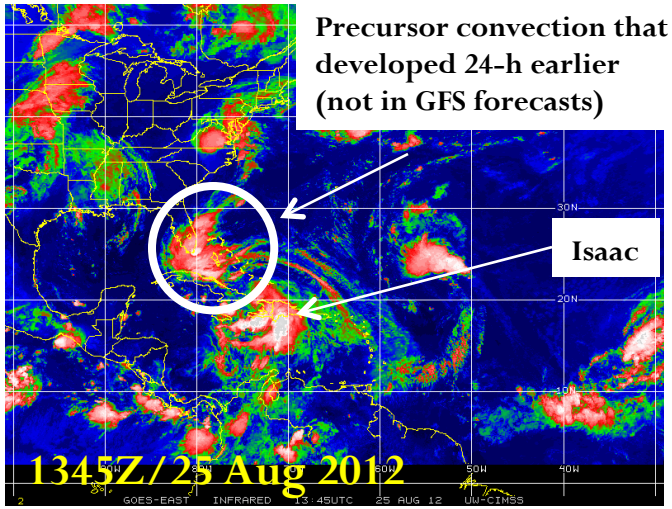
850-500 hPa seasonal mean wind

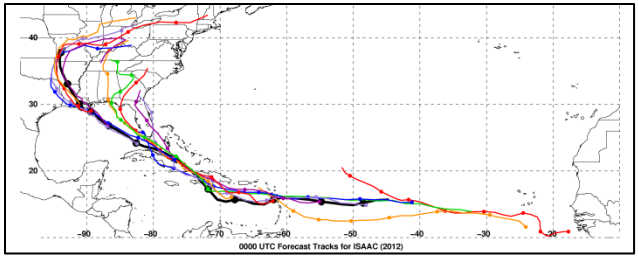


The anticyclonic circulation in eastern US in error field is related to the deamplification of a major trough in eastern US.

Case Study: Isaac Trough Fracture due to PRE convection

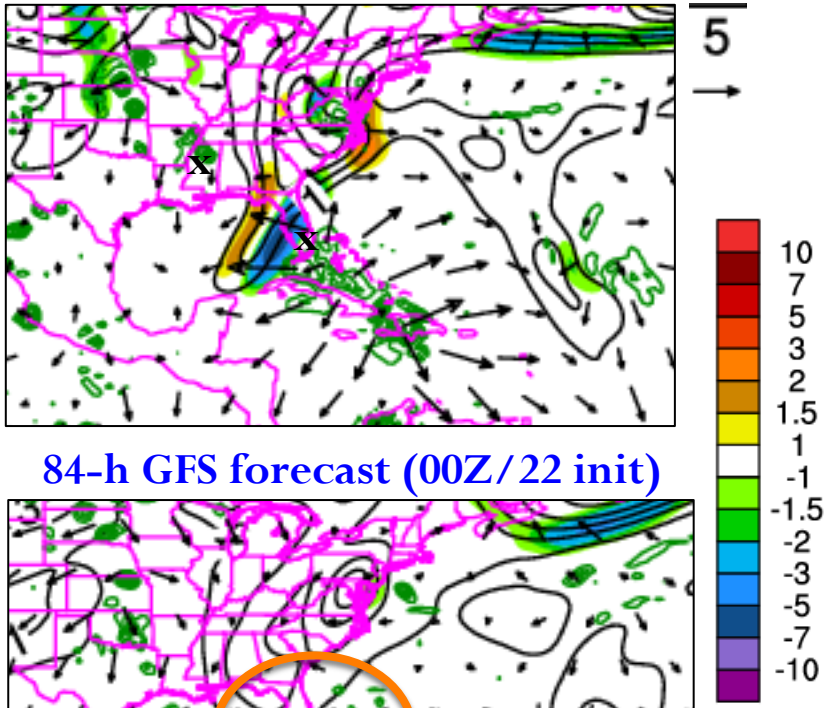
(missed by GFS)



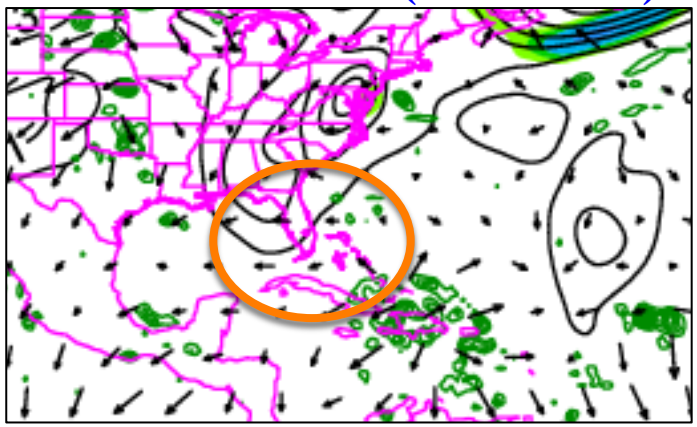


- Convective outbreak over Florida creates divergence that fractures (splits) trough
- Split in trough allows Isaac to move westward
- This process not captured by GFS

Analysis at 1200 UTC 25 Aug 2012



84-h GFS forecast (00Z/22 init)



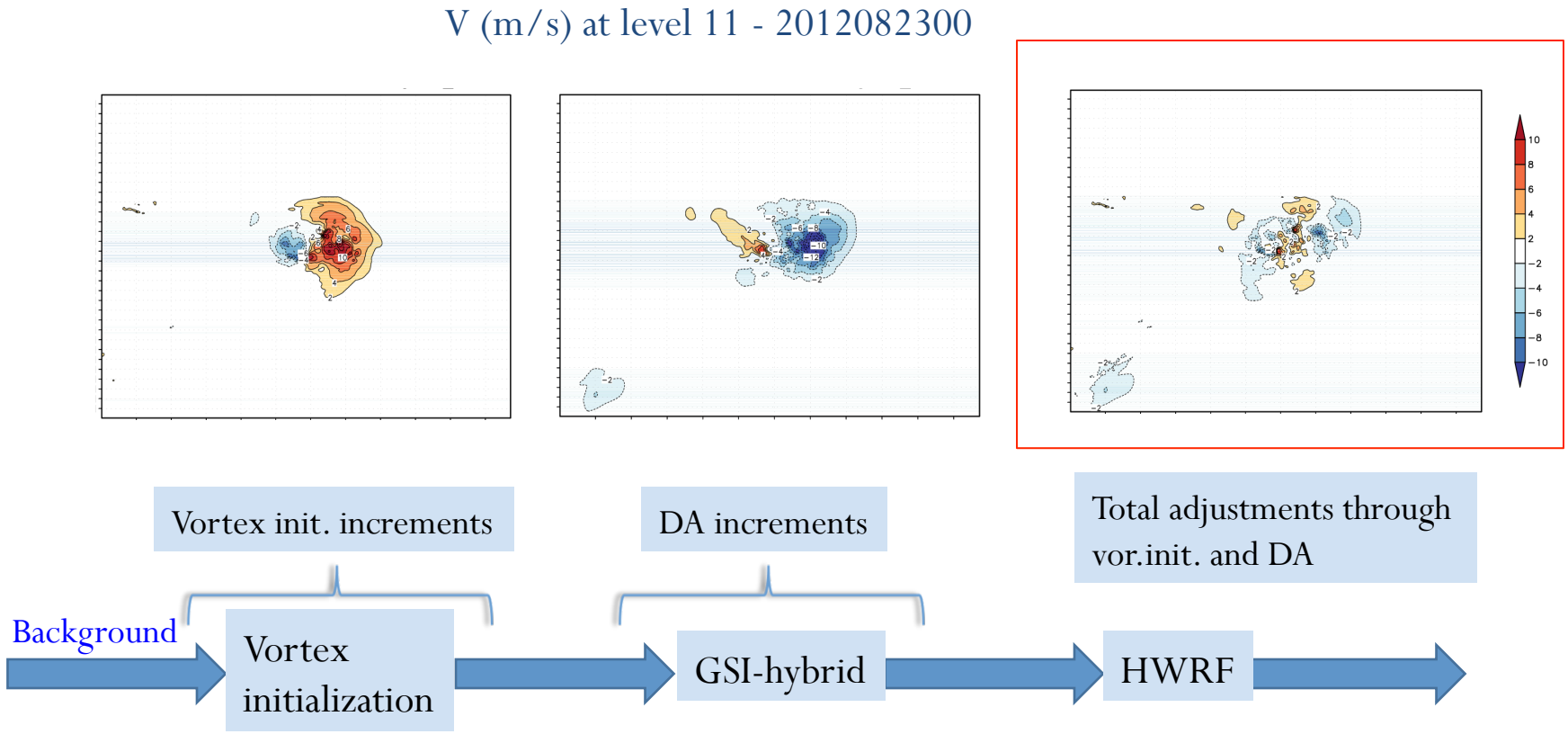
Black contours: 300–200 mb layer-mean PV (PVU)
Green contours: 600-400 mb (1 υb/s) layer-mean omega
Vectors: 300–200 hPa layer-mean irrotational wind (V_{ir}) (m/s)
Shading: 300–200 hPa layer-mean PV advection by V_{ir} (PVU/d

Hybrid Data Assimilation for Hurricane Forecasting

Hui Shao et al.

Note Joint JCSDA/DTC GSI Tutorial and Workshop

Impacts of vortex initialization & standard DA



- For this case study (with TDR data and using HWRF ensemble), the **vortex initialization counter-acts** DA analysis increments in the inner domain.

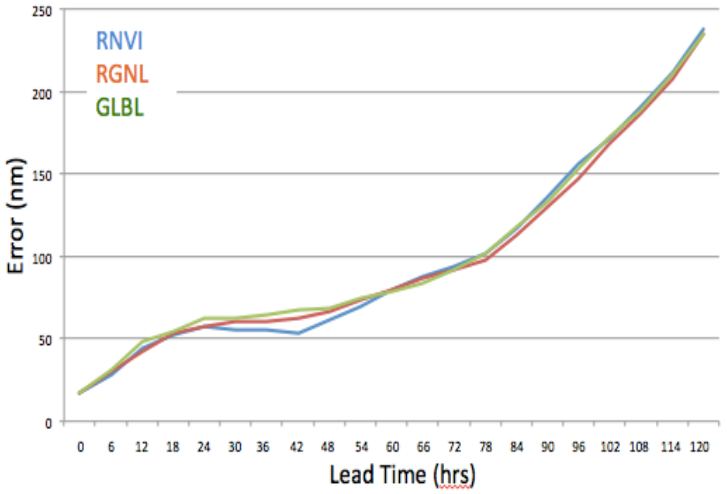
Forecast verification

GLBL: GSI-hybrid used GFS ensemble for both outer (~27km) and inner DA domain (~3km). Conventional data and TDR (when available) were assimilated

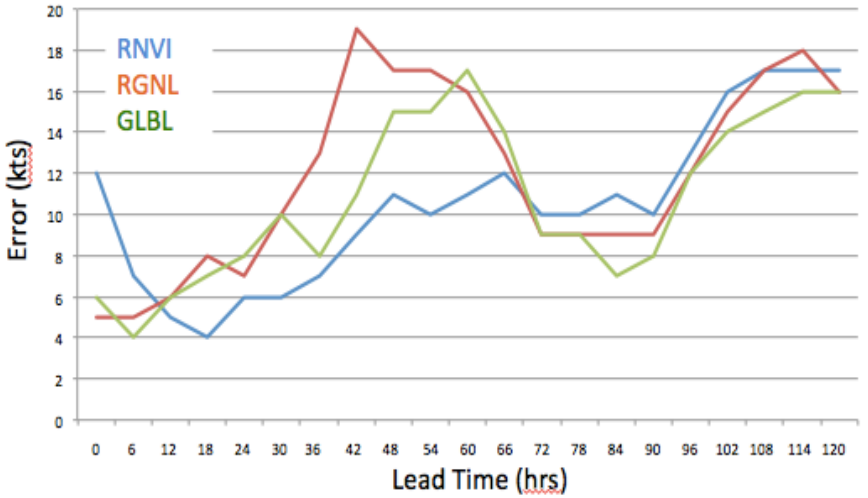
RGNL: Similar to GLBL, except DA for inner DA domain used 9km HWRF ensemble.

RNVI : Similar to RGNL, except no vortex initialization prior to DA

Aggregated abs. track errors (nm)



Aggregated abs. intensity errors (kts)



Max # of cases: 21

Highlight from Ensemble Task

Isidora Jankov, Tara Jensen, Barbara Brown, Laurie Carson, Eugene Mirvis

Port & Test Field Alignment Technique -

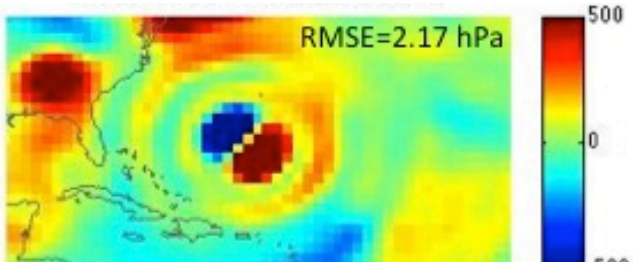
In collaboration with Sai Ravela (MIT), supported by DTC Visitor Program

- Recommendation from 2nd Ensemble User Workshop
- Tested for separating amplitude & displacement components of forecast error
- Code to be made available to the community
- Potential use in ensemble forecasting, data assimilation, verification

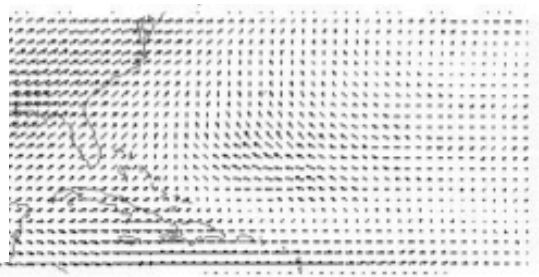
DTC Developmental Testbed Center

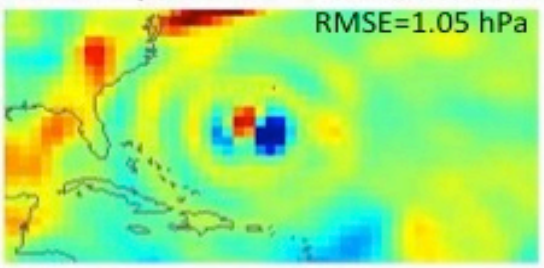
Field Alignment Technique Examples

Error decomposition, Hurricane Katia example, Sept. 6 2011, GEFS unperturbed member 12 hr Forecast, initialized at 00UTC

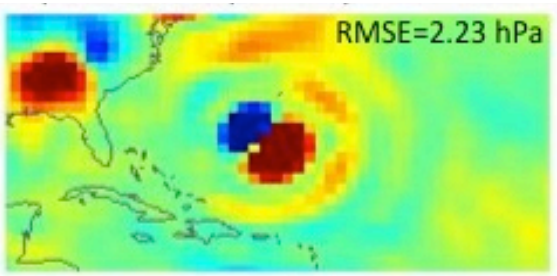


Total Error


Displacement Vector



Amplitude (Residual) Error



Change between the original and the "aligned" forecasts

Total Error 2.17 mb
Amplitude Error 1.05 mb
Displacement Error 1.12 mb

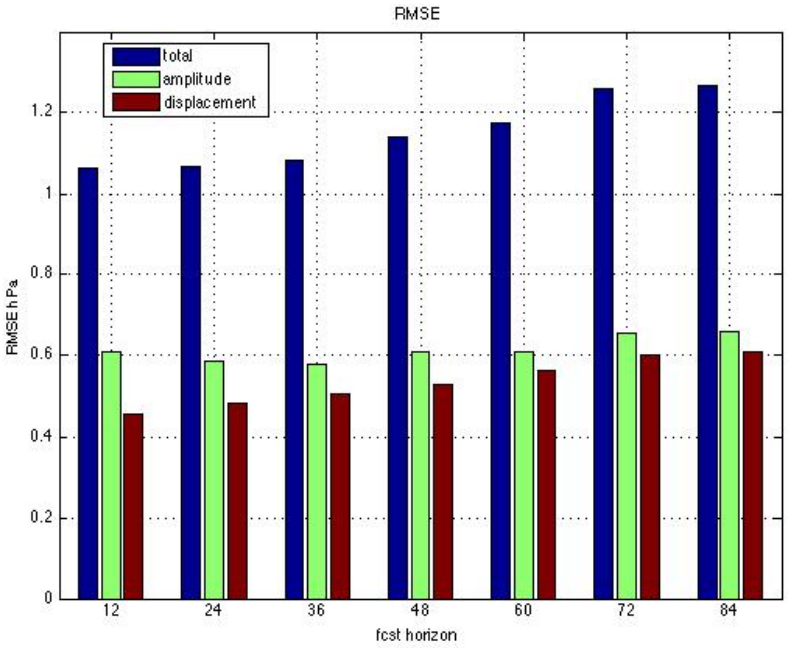
DTC Developmental Testbed Center

Courtesy of Scott Gregory

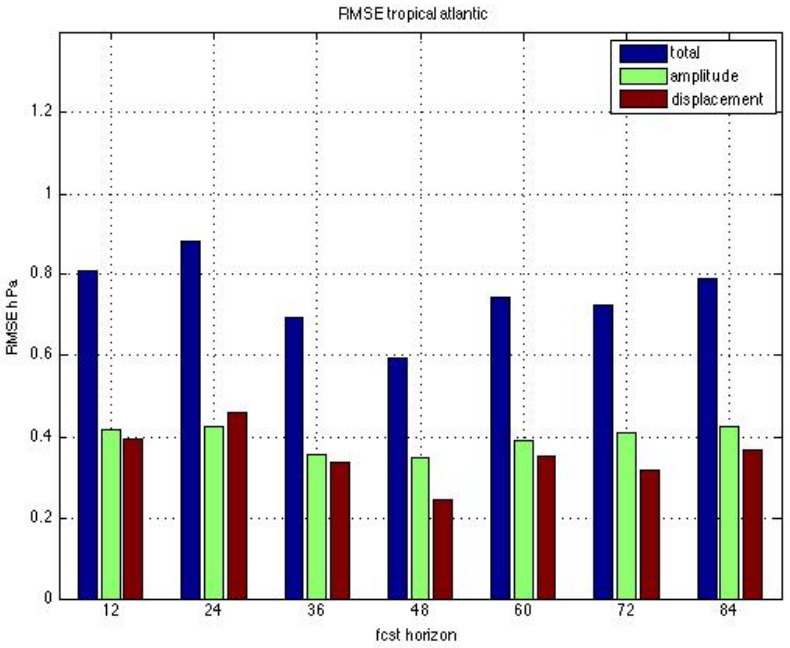
Field Alignment Technique Examples

Error decomposition with lead times for Sept 2011

GEFS unperturbed member forecasts



global domain



regional domain

Courtesy of Scott Gregory

ENSEMBLE FUNCTIONALITIES

List of centrally/locally/interactively generated products required by NCEP Service Centers for each functionality are provided in attached tables (eg., *MSLP, Z,T,U,V,RH, etc, at 925,850,700,500, 400, 300, 250, 100, etc hPa)*

	FUNCTIONALITY	CENTRALLY GENERATED	LOCALLY GENERATED	INTERACTIVE ACCESS
1	Mean of selected members *Done*			
2	Spread of selected members *Done*			
3	Median of selected values *Done Sept. 2005*			
4	Lowest value in selected members *Done Sept. 2005*			
5	Highest value in selected members *Done Sept. 2005*			
6	Range between lowest and highest values *Done Sept. 2005*			
7	Univariate exceedance probabilities for a selectable threshold value *Done, Dec 05*			
8	Multivariate (up to 5) exceedance probabilities for a selectable threshold value *Done, Dec 05*			
9	Forecast value associated with selected univariate percentile value *Done Sept. 2005*			
10	Tracking center of maxima or minima in a gridded field (eg – low pressure centers) *Done Sept. 2005*			
11	Objective grouping of members *TBS for AWIPS2*			
12	Plot Frequency / Fitted probability density function at selected location/time (lower priority) *Basic function done; Interactive version to be scheduled for AWIPS2 (TBS)*			
13	Plot Frequency / Fitted probability density as a function of forecast lead time, at selected location (lower priority) *Basic function done; Interactive version TBS*			
14	Spaghetti (ability to interactively change contour/domain etc) *Basic function done; Interactive version TBS*			

2ND ENSEMBLE USER WORKSHOP
RECOMMENDATIONS - May 18-20 2004

Additional basic GUI functionalities:

- Ability to manually select/identify members *Done*
- Ability to weight selected members *Done, Sept. 05*

Potentially useful functionalities that need further development:

- Mean/Spread/Median/Ranges for amplitude of specific features *(TBS)*
- Mean/Spread/Median/Ranges for phase of specific features *(TBS)*

- New position at CIRA / GSD
  - Ensemble forecasting research, development, testing
- CIRA position number 14-105
- http://www.cira.colostate.edu/cira-employment

Verification – Model Evaluation Tools (MET)

Tressa Fowler et al.

MET v4.1 – Released May 2013

- Spread skill statistic in ensemble tool with plotting capability added to METViewer.
- Series analysis tool summarizes verification statistics in any series (e.g. time, height) at each grid point in domain.
- little_r and SURFRAD handled in preprocessing tools.
- MET – TC to support verification of tropical cyclone forecasts (supported by HFIP)

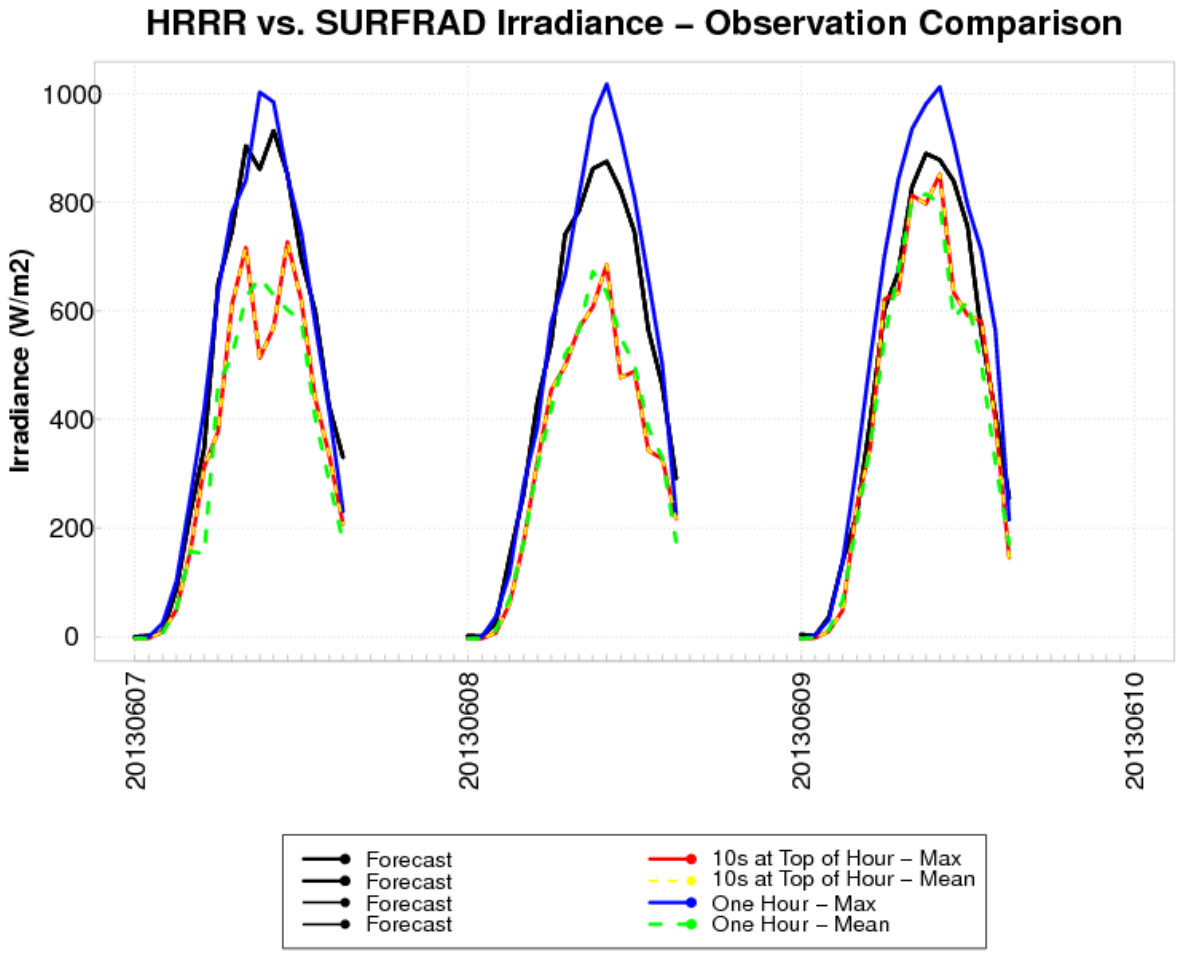
MET v4.2 – Release Imminent

- NetCDF CF support.
- Automatic configuration (autoconf) to eliminate user responsibility for adjusting code for different compilers.
- Smaller (approx 80% reduction) postscript image files produced by MODE and other tools.

MET v4.2 – Release Imminent

- Updated support for TRMM data.
- More contingency table statistics, including bias corrected ETS and extreme dependency scores.
- Enhancements to MET – TC to support verification of tropical cyclone forecasts (supported by HFIP)

SURFRAD preprocessing and ability to summarize observations over time



RECENT DEVELOPMENTS

INTERAGENCY COLLABORATION

- **Cooperative agreement**
  - NOAA's 5-yr agreement with NCAR expired Aug 2013
  - Continued engagement with NCAR
  - Looking for new long term funding vehicle

- **DTC Charter**
  - Signed by NWS, OAR, AFWA, NCAR in 2009
  - Up for possible revisions in Sept 2014
  - DTC MB will make recommendations
    - Need to clarify terms of interagency operations

ROLES & RESPONSIBILITIES

- **DTC EC Meeting – Febr 2014**
  - Discussion and clarification of roles & responsibilities
    - DTC Director (Bill Kuo)
      - Coordinate planning, monitor progress
    - NCAR/RAL, GSD
      - Execution
  - Clearly defined tasks with deliverables for RAL & GSD

- **NWS – OAR Discussions**
  - Role of two line offices in NOAA's DTC efforts
  - NOAA's role in interagency DTC
  - NOAA's priorities
    - R2O areas
    - Ways to best engage community

POSSIBLE FUTURE DIRECTIONS –

PERSONAL PERSPECTIVES

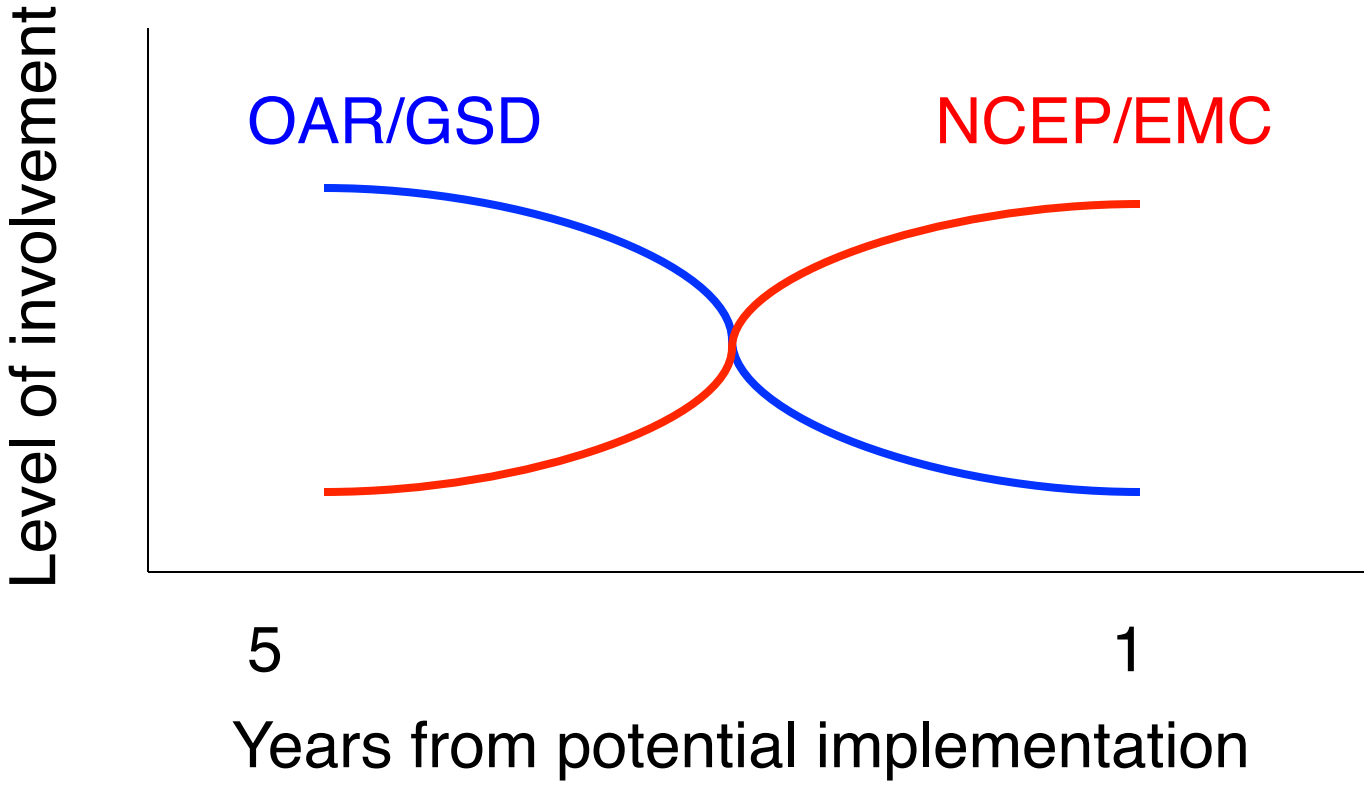
TIME SCALE OF TRANSITION

- **~1 year – Next NCEP Implementation**
  - Clearly connected to NCEP AOP
  - Modest impact – most work done earlier
  - Hard to engage with hectic EMC activities prior to implementation
  - Primary role of EMC

- **2-3 years – Evolution of current system**
  - Moderate risk of no direct contribution to operations
  - Potential for larger impact
  - Good practices needed for DTC – EMC interactions
  - EMC needs support

- **3-5+ yrs – Next generation system**
  - Higher risk – High level of NWP expertise needed
  - Highest potential for impact
  - Good partnership with EMC is critical
  - Clear role for OAR

ROLES IN R2O TRANSITION IN NOAA

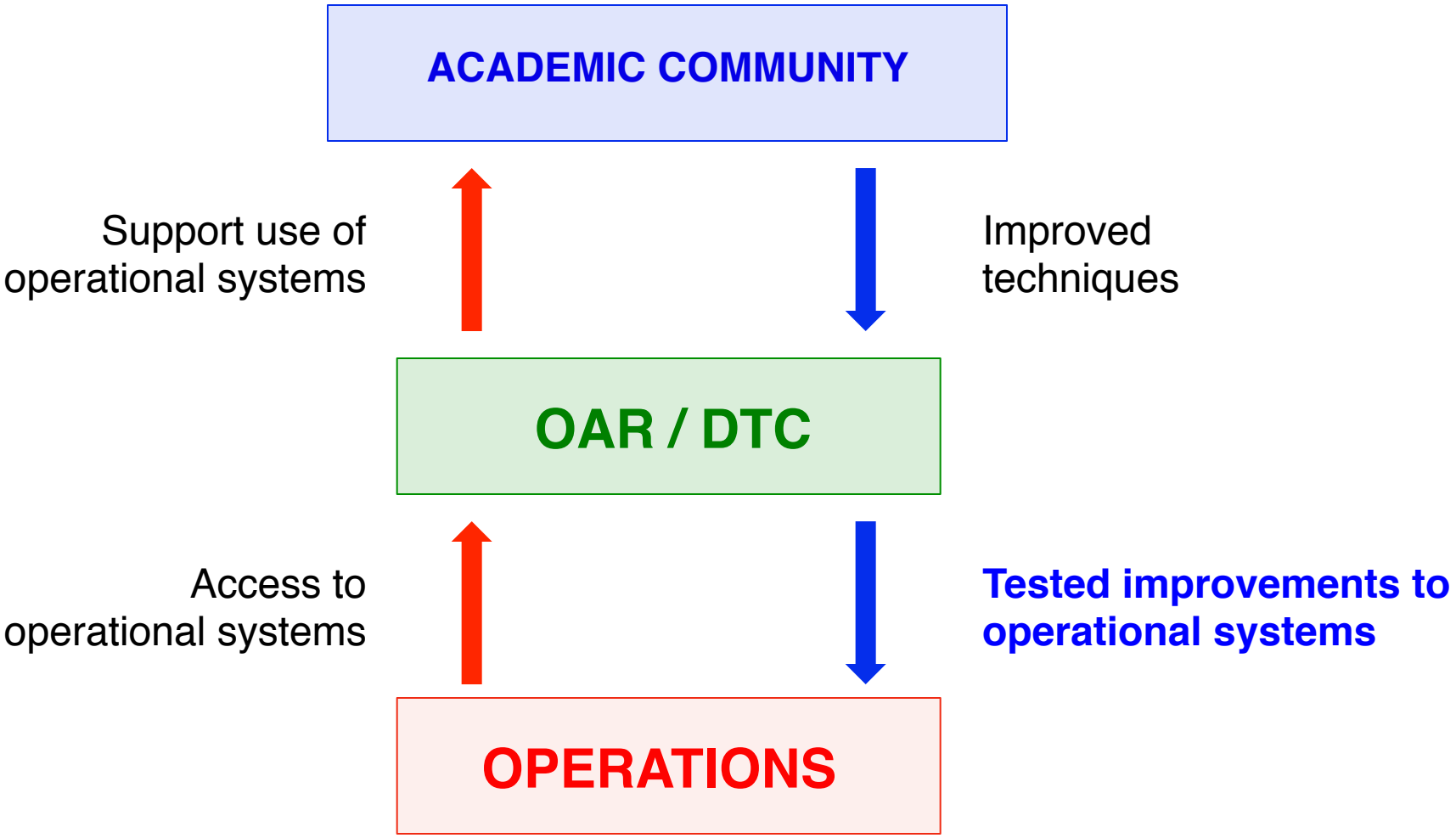


ROLES OF NWS & OAR

- **NWS – EMC**
  - Lead O2R
  - Lead short term R2O
  - Provide expected operational requirements & constraints

- **OAR - GSD**
  - Lead long term R2O
  - Engage with diverse research community
  - Build prototypes of next generation systems
  - Orchestrate seamless handoff to operations

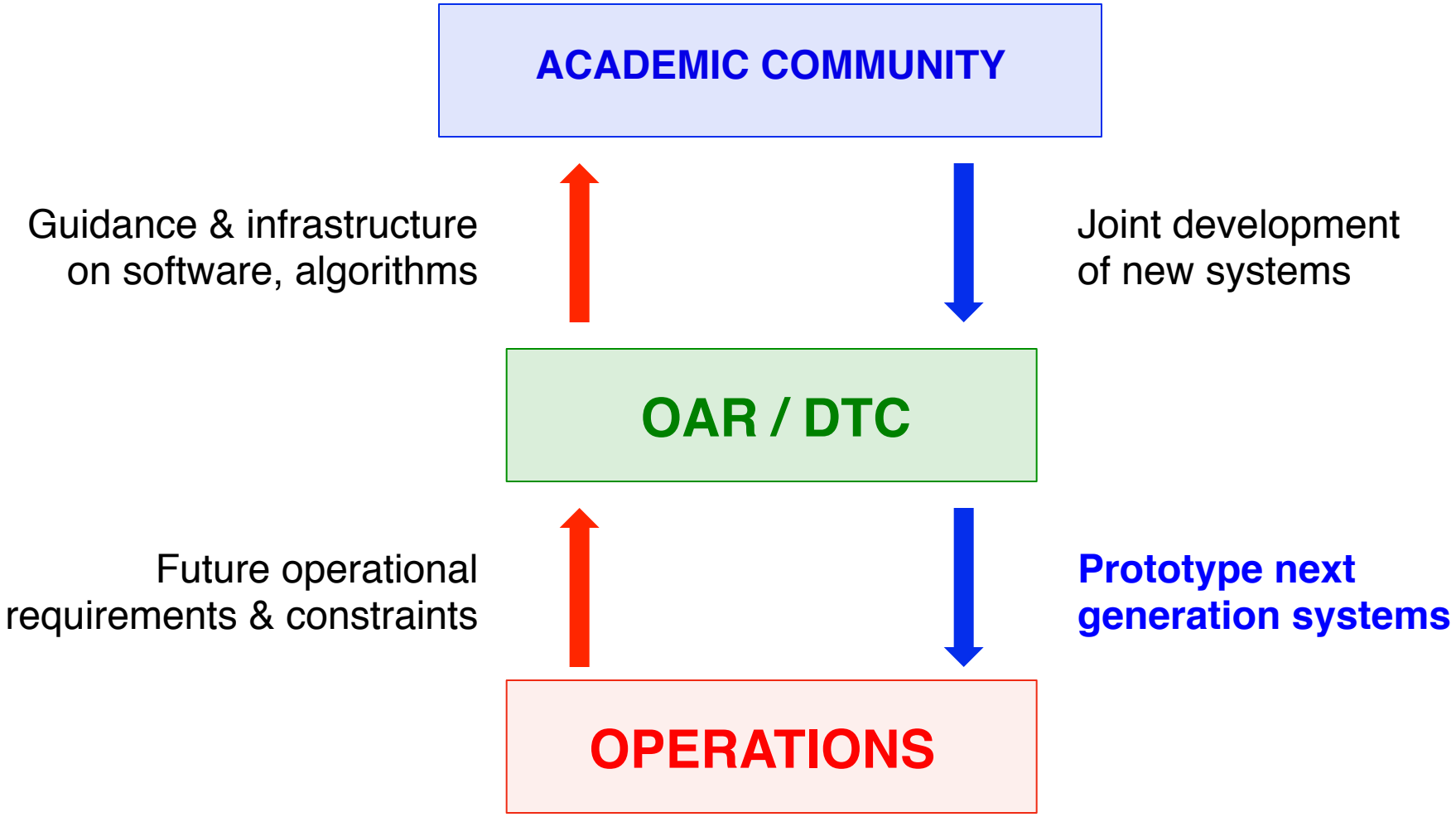
CURRENT OPERATIONAL SYSTEMS



Driven by Operations

NEXT GENERATION SYSTEMS

Driven by Research



OUTREACH TO ACADEMIC COMMUNITY

- **Create open Working Groups**
  - Follow JCSDA example
  - Invite all parties doing related work, irrespective of funding source
- **Canvass NSF grantees**
  - Support selected scientists' related R2O work
  - NOAA R2O AO?
    - Leverage huge government investment
- **Provide advanced NWP Information Technology Environment (NITE)**
  - Shaped after ECMWF's example
  - Interconnected database, DA/model launcher, display, verification, etc tools
  - Same system used by EMC, DTC/OAR, external contributors
  - Significant upfront investment – Big gain later
    - The later done, the more expensive it will be
  - Feasibility study by DTC in AOP14

DTC & OTHER TESTBEDS

- **Application oriented testbeds – HMT, HWT, JHT, AWT, CTB**
  - NWP related testing
    - DTC to provide support
    - Testbeds to take part in evaluation

- **NWP-related testbed - JCSDA**
  - Overlap in data assimilation
    - JCSDA – Use of satellite DA
    - DTC – DA methodologies
  - Join forces for pulling in new technology
    - Build & share object oriented DA repository
      - Will allow plug & play software intercompatibility
  - Clarify areas of primary interest
    - For more efficient outreach

FUTURE SCOPE

- **DTC must focus on**
  - Gaps in R2O, not covered by other programs
  - Cutting edge development areas
  - Limited resources – must be selective

- **Shift focus onto global forecasting?**
  - Apply mesoscale experience with Limited Area Forecasting (LAF) to global forecasting
  - Leverage DTC tools (testing, verification, DA, physics, ensemble, etc methods)
  - Overlap with other projects (OAR Sandy Supplemental & NWS R2O projects)

- **Keep focus on Limited Area Forecasting?**
  - Build on past experience in DTC
  - Narrow focus onto Warn-On-Forecast (WOF)
    - Mesoscale covered by today's/tomorrow's global forecast systems

OUTLINE / SUMMARY

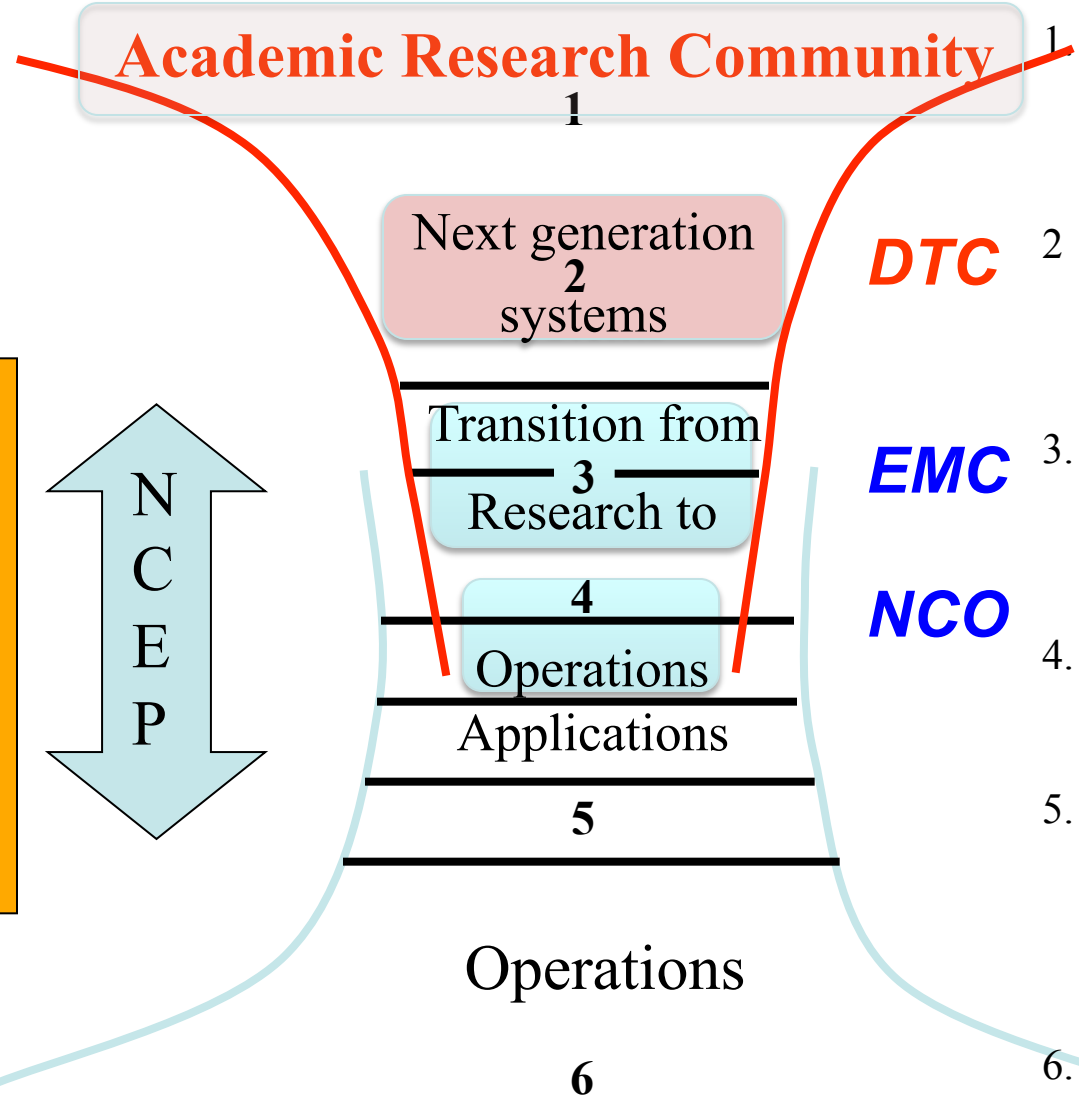
- **Where DTC has been**
  - Operations to Research (O2R) in Numerical Weather Prediction
    - Code repositories, helpdesks, tutorials, etc

- **AOP-13 Highlights**
  - Mesoscale modeling, Hurricane modeling, Data Assimilation, Ensemble forecasting, Verification
    - Testing & Evaluation of baseline & other methodologies

- **Future Directions**
  - Discussions on scope of DTC
    - Improve current & next generation NWP systems
    - New Cooperative Agreement
  - Build modern NWP IT Environment (NITE)
  - Strengthen collaboration with other NOAA testbeds & programs

BACKGROUND

Applying the "Funnel" to the Transition Process



NCEP is uniquely positioned to provide an operational infrastructure for the transition process

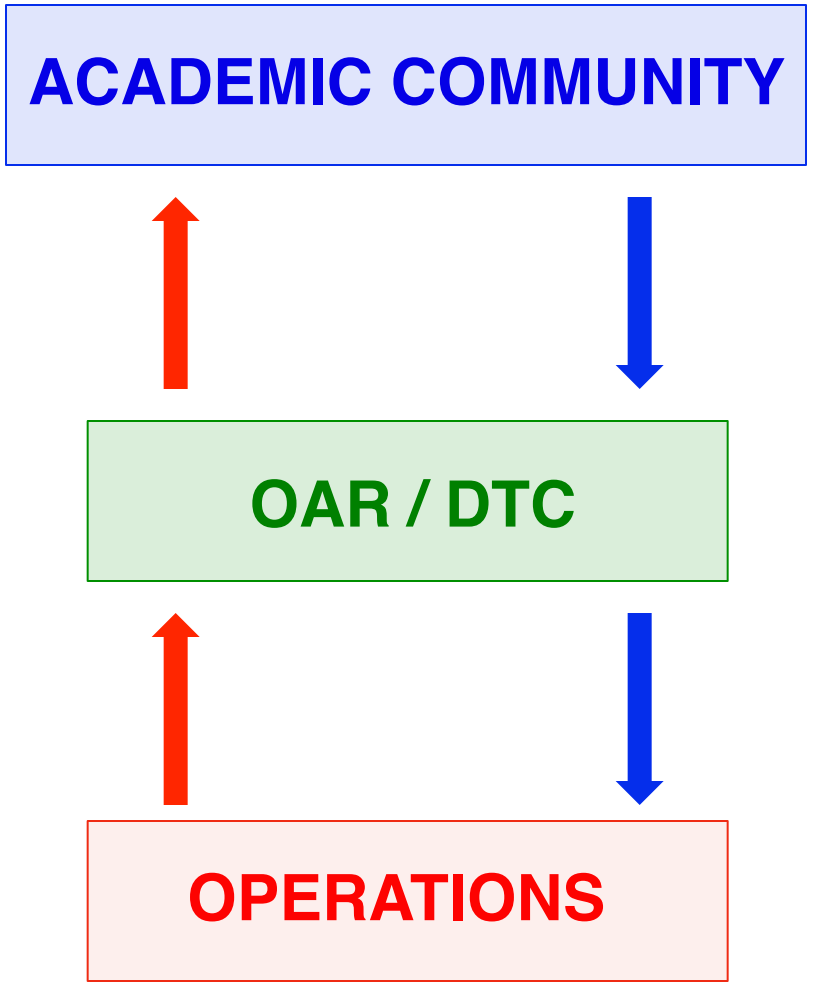
NCEP

1. Large "volume" of academic / agency lab R&D, 5 yrs
2. Smaller set of R&D products suitable for operations. 3 yrs
3. Systematic transition steps. 1 yr
4. Operations - Current
5. New products can serve diverse and expanding user community.
6. Delivery to diverse USER community

After A. MacDonald & L. Uccellini

ROLES - NEXT GENERATION SYSTEMS

Driven by Research



- Develop new methods applicable in operations

CRITERIA

- *Serves user needs*
- *Scientific soundness*
- *Quality of results*
- *Computational efficiency*
- *Ease of implementation & maintenance*

- Bridge academia & operations
- Identify promising techniques w. community
- Assemble prototype systems w. community
- Evaluate prototypes w. EMC using criteria

- Advise on future user needs
- Advise on implementation/maintenance needs
- Pre-implementation testing

BACKGROUND

BACKGROUND

- **History**
  - Initiated in 2004; NOAA funding increases in 2009 & 2010
- **Organization**
  - Interagency level – Charter – Bill Kuo, Director
    - NOAA, NSF, NCAR, USAF
  - NOAA level
    - OAR-GSD, HFIP, USWRP, with EMC support
- **Staffing**
  - NCAR/RAL – Under NOAA Cooperative Agreement
  - ESRL/GSD
- **NOAA Cooperative Agreement**
  - Present - NCAR, 2008-2013
  - Next phase – 2014-2019
    - Announcement of Opportunity being prepared
      - Competitive process
  - Opportunity for NOAA to take stock and make adjustments if necessary

OVERVIEW

- **Objective**
  - Accelerate NWP Research to Operations (R2O) transition
- **Approach**
  - O2R
    - Make operational NWP systems available to research community
      - Code repositories, helpdesk, tutorials, etc
  - Test and Evaluation (T&E) of emerging research innovations
  - Engage community
    - Workshops, Visitor Program, etc
- **Task areas**
  - Mesoscale modeling (WRF ARW, NMMe, NMMb)
  - Data assimilation (GSI)
  - Hurricane forecasting (HWRF)
  - Ensemble forecasting (SREF)
  - Verification (MET)
- **Links with other NOAA Testbeds & programs**
  - HMT, HWT, HFIP

BACKGROUND